Electra Pre-Amp Guide Field Magnet Coils

November 7, 2003

1. Introduction:

The Laser Plasma Branch of the Naval Research Laboratory has a requirement for an electromagnet (hereinafter referred to as the magnet) to provide a guide field for the electron beam pumped Electra Pre-Amplifier Laser. The magnet is to produce a magnetic field in a rectangular volume of approximately 100 cm x 10 cm x 20 cm. The magnetic field at the center of this volume is to be oriented perpendicular to the 100 cm x 10 cm plane. The magnet will be energized by a power supply that is capable of 140 Volts at 1000 Amperes. At this current the magnetic field is expected to be 2100 Gauss. The magnet will be water cooled. The magnet will typically run 5-6 hours per day, two times per week. However, there will be extended runs of 60 hour each. The operational life of the magnet is anticipated to be more than ten years.

The contractor will be responsible for building the magnet (coils), magnet housing (cans), magnet can spacer assemblies, and all electrical/water terminations and installing temperature sensors on each winding. The contractor will be responsible for performing and documenting interim tests of the magnet insulation and performance, and producing final drawings of the magnet assembly. The contractor is responsible for shipping the completed magnet system to NRL. NRL will be responsible for installing the magnet, hooking it up to the existing water supply and power source, and testing the magnet.

The specifications are listed below in Section 2 as performance specifications along with interface requirements, constraints, geometric limits, and tolerances. There are six attachments, engineering drawings numbered N03-001, N03-002, N03-003, N03-004, and N03-005, which give the geometric limits and tolerances in further detail. These drawings shall be considered part of this specification package.

2. Specifications

2.1 General layout: The magnet consists of two coils in a race track configuration. Each coil is comprised of 10 individual conductors Each magnet coil is mounted in a separate aluminum structure, or "can". The completed magnet assembly is shown in Drawing N03-001. The cans are separated by 17.15 cm (6.75"). As shown in drawing N03-003, the cans have a clear aperture of 133.4 cm x 45.7 cm (52.5" x 18.0"). The cans provide support points for mounting the coils, support the coils against the magnetic forces, and protect the coils during shipping and installation. They may also serve as potting molds (contractor option).

2.2 Coil Configuration and placement: The coil configuration and placement is shown in Drawing N03-002. Each coil consists of 10 individual conductors wound "two in hand" (winding two conductors together as if they are one, but insulated from each other) into five "double pancakes." There are 10 radial turns in each coil, so each double

pancake has a total of 20 turns. The double pancakes within each coil shall be laid in such that the layer-to-layer transitions in adjacent double pancakes shall alternate in sense.

2.3 Conductor: Each conductor is 0.5 inches square nominal dimension, has .060" radius corners and is hollow with a 0..21-25-inch nominal round ID for water cooling. The conductor is to be made from OFHC copper, with a resistivity of less than or equal to 30 micro- ohms/foot. Each conductor shall be continuous within the coil with no internal splices, joints, or electrical connections permitted.

2.4 Insulation system: The contractor shall design the insulation system to provide a minimum service lifetime of 10 years at a maximum service temperature of 60 degrees centigrade. Taping and spacing shall provide for good penetration of the epoxy into the inter-conductor spaces. The coils operate at a maximum turn-to-turn voltage of approximately 10 volts. The coils shall be vacuum potted to assure good epoxy penetration and minimum voids and bubbles. No void or bubble should entirely bridge the gap between the conductors. Each coil shall be vacuum potted as one integral block. The contractor shall add no filler that reduces the optical transmission of the cured epoxy. This is to maximize the ability to inspect the potted windings for bubbles and voids during the assembly. Note, however, that any exposed surface of the coil will be painted black before delivery (see 2.29).

2.5 Coil dimensions: Each completed coil should have an axial thickness of 5.50 +0.25/- 0.20". See Drawing N03-002.

2.6 Termination location All conductor ends shall exit in the same area of the coil, as shown in Drawing N03-001. The region used for these conductors shall be approximately 8 inches in extent (measured as an arc along the outside perimeter of the coil). The termination area starts at 15° below the horizontal of one of the extreme ends of the racetrack, and ends at 45° below the horizontal (the terminations are on the lower half of the coil, adjacent to the stand supports). The longitudinal dimension is determined by the final can thickness, which is determined by the contractor. In the tangential direction the contractor is encouraged to space out the conductors to improve accessibility and ease of working on the terminations.

2.7 Length of exposed ends of conductors: Every conductor end shall individually exit the potting epoxy with not less than 5 inches of usable exposed end. There shall be no electrical or cooling water connection between conductors inside the epoxy nor within 4 inches of the epoxy surface externally. All terminations and cooling manifolds and connections must be contained within the volume specified in Drawing N03-001.

2.8 Terminations- electrical connections: All conductors within a coil shall be connected in electrical series in such manner as to maximize the self-inductance of the coil; i.e. so that the resulting fields add. The self- inductance of each coil should be greater than 18 milliHenries. (For reference, the government estimates that it should be 20 milliHenries.). Since the double pancakes are laid in with alternating senses of layer-

to-layer transitions, note that this is not a simple series connection of the conductor ends as they emerge from the potting.

2.9 Terminations: mechanical connections: The electrical connections shall be accomplished by forming each pair of conductors so their ends are parallel to each other and brazing the conductors together for at least one inch, at least 4 inches from the epoxy. The two end connections to each coil shall have lugs (or "flags") brazed to the exposed ends, with ratings of not less than 1250 amperes RMS AC or DC. There shall be no charring of the exposed insulation. See Drawing N03-002.

2.10 Cooling Connections: There is one water fitting for every two conductor ends, plus a fitting on each of the two single conductor ends. Thus each coil includes 11 water fittings, 9 on pairs of conductor ends plus two on the single conductor ends. The water fitting shall be made of a material that is galvanically compatible with the conductor. The fitting should be brazed to the conductor. See Drawing xxx-003.

2.11 Shock resistance of terminations: All leads should be supported for a bending force of 200 lb and a twisting force of 100 lb.

2.12 Thermal Sensors: Each end of each conductor shall have a thermal sensor switch where it emerges from the epoxy of the coil, as close to the epoxy interface as feasible and as far away from the water fitting caps as feasible. Each sensor shall be a thermal switch, normally closed at room temperature, with an opening temperature not to exceed 160 degrees F (70 degrees C) and not to be less than 140 degrees F (60 degrees C). Each switch shall be individually tested by the switch manufacturer. Use of appropriate UL listed or UL recognized components may be used to satisfy this requirement. Alternatively, the contractor may individually test each switch prior to installation.

Each thermal switch shall be mounted in a mechanically secure fashion to assure permanent, good thermal contact with the conductor. The following methods are typical of those that are acceptable:

A switch with a single stud integral to the switch body, screwed into a copper or brass block brazed to the conductor, with thermal heat sink (silicone) grease on the threads and under the switch body

A copper or brass block brazed to the conductor with two protruding studs matching holes in the thermal switch body, with the switch secured by nuts and lock washers on both studs and with thermally conductive epoxy in the interface between the switch body and the copper or brass block face

Two-hole mounting switches, with individual clamps that surround the conductor and provide a surface level with the conductor face with either two studs or two tapped holes for mounting the switch, with thermally conductive epoxy in the interface between the switch body and the conductor face.

Switches with rectangular or cylindrical bodies, mounted to the conductor surface with thermally conductive epoxy and secured in place with two "tie wraps" rated for at least 150 degrees C service. The free ends of the tie wraps shall be trimmed nearly flush.

The following is an example of a mounting that is NOT acceptable:

Mounting methods that deform the switch body or depend upon spring forces in the switch body to make thermal contact. This technique is not acceptable, even if it used in conjunction with thermal grease or epoxy between the switch body and the conductor face.

2.13 Thermal switch connections: All switches on a coil (20 of them) shall be wired in electrical series. The two remaining leads shall be brought to a terminal strip mounted in a protected location on the can near the coil terminations.

2.14 Cooling manifolds: The contractor shall design, fabricate, and deliver four water cooling manifolds, one for the inlet and one for the outlet for each coil. There are 11 water connections per coil, 6 inlet (4 double and 2 single) plus 5 outlet (all double). Cooling manifolds shall be securely mounted to the coil mounting cans. The method of mounting is contractor choice. The mountings must be able to be disassembled. The mountings, manifolds, and (after installation) supply/return piping may not extend beyond the "inside face" nor the "outside face" of the coil cans. See Drawing N03-001 for the definition of inside face and outside face and the location of the allowable region.

2.15 Cooling manifold material: The choice of material of the cooling manifold is up to the contractor. However, if the manifolds are electrically conductive, they 1) shall be effectively insulated by their mounting from the coil mounting can, and 2) shall be fabricated solely from copper and/or brass to be galvanically compatible with the coil conductors.

2.16 Cooling manifold connection to water fittings: The manifolds shall be connected to the water fittings on the coils with flexible, electrically insulating, repairable, water compatible hoses rated at not less than 200 PSIG working pressure. The minimum hose ID shall be 0.25 inches and the minimum hose length shall be 12 inches. Connections shall be made to assure coolant flow through every conductor in parallel.

2.17 Cooling manifold connections: Each manifold shall include a 1-1/4 inch female tapered pipe thread to accept a standard 1-1/4 inch male NPT fitting. The female threads shall fully conform to US national tapered pipe thread standards.

2.18 Mounting cans: Each coil assembly is mounted in an aluminum structure, called a "can." The geometric restraints on the cans are shown in Drawing N03-003. All external edges of the can are broken so there are no sharp edges. The coil is to be securely held in the can by mechanical means and secured with bolts. Drawings N03-003 and N03-005 offer a suggestion as to how his may be done. It is the contractor's responsibility to

provide cans that can adequately contain the magnet in the presence of the magnetic forces acting on it. The net attractive force between the two coils is approximately 6000 lbs.

2.19 Coil padding, face: A sheet of 1/8-inch nominal thickness silicone rubber should be placed between the face of the coil and metal can. The inner face shall be fully covered with this rubber. The outer face need only be covered in the area where the coil is held (for example, under the coil clamps). In no case shall the metal can come in direct contact with the coil face.

2.20 Coil padding, perimeter: The coils shall be cushioned at the inner and outer perimeter with 1/8-inch nominal thickness silicone rubber, as shown in Drawing N03-001. The rubber can be applied in strips, and need not be continuous. It is up to the contractor to determine the number and location of these strips.

2.21 Coil padding material: All rubber sheeting and shims shall be flame resistant per UL 94 V-O or approved equivalent. The coil padding shall be independently secured to the can, and not just by the compressive force between can and coil. Examples include RTV sealant. The actual securing method is determined by the contractor.

2.22 Can topology: The inside face of the can where the coil is supported must be continuous with no penetrations. Weldment drawing N03-003 illustrates an additional 0.5 inch thick doubler welded into the inside face of the can with through holes for securing the inter-coil spacers. These holes are drilled and tapped prior to welding, and only penetrate this added doubler plate.

2.23 Can mounting brackets. The cans must have mounting brackets in the locations shown in Drawing N03-003. **It is the contractor's responsibility to design these brackets to withstand the magnetic and gravitational forces.**

2.24 Mounting bracket bolt pattern. Each bracket should have the bolt pattern shown in the inset in Drawing N03-003. This is for mounting the magnet assembly to a support structure. NRL will provide the support structure.

2.25 Spacer assemblies. The magnet assembly must include four spacer assemblies to hold the two cans at a fixed separation and relative position. A suitable design is shown in Drawing N03-004. The spacer assemblies must be strong enough to sustain the compression force resulting from the mutual attraction of the two magnets. This force is estimated to be 6000 lb. The spacer assemblies must be located in the positions shown in Drawings N03-001 and N03-003.

2.26 Ferromagnetic materials. No ferromagnetic materials may be used in this unit.

2.27 Lifting attachments: Each coil must have lifting attachment points so it can be lifted with an overhead crane capable of lifting 15,000 lbs., with a hook height of 228 inches.

2.28 Labeling of electrical /water connections. All electrical, thermal sensor, and water terminations that are to be connected to external components must be clearly marked.

2.29 Magnet external appearance. All exposed surfaces of the magnet coils and cans should be painted semi gloss black. This includes the inside face, the outside face, the inner perimeter, and the outer perimeter. See Drawing N03-001 for the definitions of these surfaces. The paint should be compatible with aluminum, and impervious to alcohol. A two part epoxy paint is preferred. It is not necessary to paint the exposed bolt heads, the cooling manifolds, the wire terminations, or any other component whose function would be compromised by painting.

2.30 Appearance: Appearance to reflect good workmanship.

2.31 Warranty: One year warranty for defects in materials and workmanship.

3. Additional Requirements

3.1 Testing: The contractor must perform the following tests during the fabrication of these coils. In all cases, these tests are to be performed on all components of the system, not just a representative sample:

3.1.1 Hi pot testing conductors: The individual conductors shall be hi-pot tested, conductor-to-conductor and conductor-to-mold, after potting and prior to removal from the mold. The hi-pot test voltage shall be 1500 +/- 150 Volts DC, and the test duration should be at least 1 minute. Leakage currents shall not exceed 5 microamperes conductor-to-conductor and conductor-to-mold.

3.1.2 Impulse testing: Prior to final mounting in the cans, each coil shall be impulse tested and the inductance and resistance shall be measured. The inductance is expected to be approximately 20 millihenries, plus or minus 3 millihenries. As an alternative to measuring the inductance, the contractor may measure the magnetic field, provided a satisfactory impulse test has been performed. A field measurement must be made at the geometrical center of the coil at a current of not less than 25 amperes, using an instrument accurate within plus/minus 2 percent.

3.1.3 Hi pot testing coils: After final mounting in the cans and after all electrical connections between conductors are brazed and water fittings installed, the contractor shall hi-pot test each coil to its mounting can. Hi pot specs are the same as for the individual coils: 1500 +/- 150 Volts DC, and the duration of the test should be at least 1 minute. Leakage currents shall not exceed 5 microamperes DC conductor-to-conductor and conductor-to-can.

3.1.4 Hydrostatic test of cooling channels: All conductor cooling channels shall be hydrostatically tested to 300 PSIG after installation of the fittings.

3.1.5 Hydrostatic test of entire coil: The entire water circuit of each coil, including hoses and manifolds, shall be hydrostatically tested to 150 PSIG minimum after assembly. NOTE -- The contractor may choose to combine this with the conductor hydrostatic test at 300 PSIG provided the manifolds, fittings, and hoses are rated for working pressures exceeding the test pressure.

3.2 Documentation:

The contractor shall submit the following documentation: (Certification is meant to denote both a description of the test method and the results).

3.2.1 All as built drawings of the magnet coils, cans, electrical wiring, terminations, water fittings, coil shims.

3.2.2 Certification of hi-pot tests of individual conductor pairs, in mold.

3.2.3 Certification of hi-pot tests of coil inside can.

3.2.4 Inductance and resistance measurement of each coil (alternatively, a map of the magnetic field at a current of not less than 25 Amperes).

3.2.5 Certification of copper used in the conductors.

3.2.6 Any documentation supplied the manufacturer of the thermal sensors. If the contractor elects to test the switches rather than use pre-tested and certified switches, the documentation must include the test plan and test results.

3.2.7 Certification of the hydrostatic waster tests.

4 Reviews and acceptance.

4.1 Periodic Reviews: The contractor shall hold the following reviews, at his manufacturing plant. Government personnel and/or representatives will attend these reviews. The primary purpose of these reviews is to resolve any potential interfacing requirements, and to make sure that all specifications can be met. No formal documentation is required at these reviews other than the working drawings, calculations, etc. that would normally be produced in the course of this project. It is anticipated that these reviews will be short (few hours) in duration. It may be possible to accomplish some of them through e-mails, faxes, and phone calls. These reviews include:

4.1.1 Preliminary design review: to discuss requirements, interface issues and specifications

4.1.2 Conceptual Design Review: to discuss design of these electromagnets

4.1.3 Final Design Review: Review final engineering drawings.

4.1.4 Preliminary acceptance of finished product: Inspect for workmanship, proper placement of manifolds, obvious flaws, etc

4.2 Inspections. The government reserves the right to inspect any of the following during the coil fabrication and assembly:

4.2.1 All conductors prior to and during taping and winding.

4.2.2 The contractor's proposed insulation system prior to commencement of winding.

4.2.3 Conductor taping prior to and during winding.

4.2.4 The lay-up of transitions before and/or after potting.

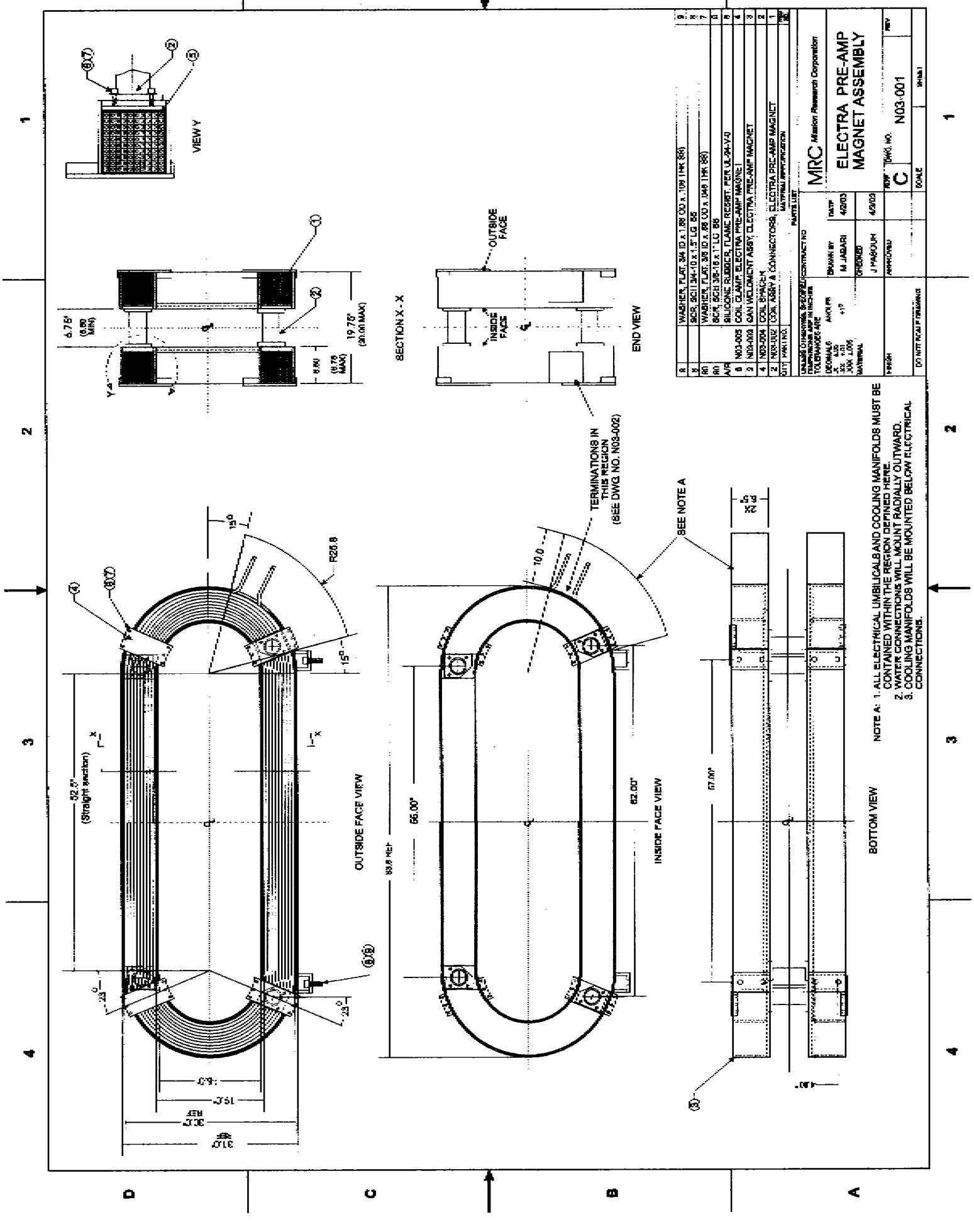
4.2.5 Inspect the vacuum potting plan, molds, pumps, and related hardware prior to potting.

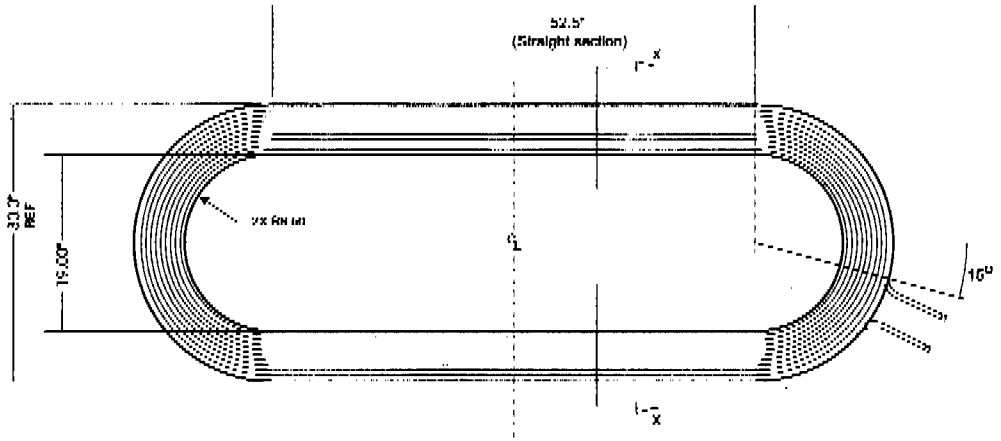
4.2.6 Inspect all potting for voids.

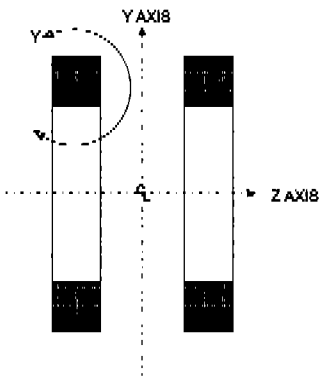
5 Acceptance:

5.1 Preliminary acceptance shall be made at the contractor's plant prior to shipping.

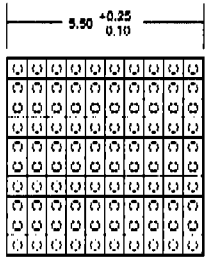
5.2 Final acceptance shall be made at the Naval Research Laboratory after installation and testing. The test will consist of two 5 hour long cycles, and will include: verification of the winding senses; cooling circuit integrity, and electrical insulation integrity.


VIEW Y
SECTION X - X
END VIEW
OUTSIDE FACE
INSIDE FACE
TERMINATIONS IN THIS REGION (SEE DWG. NO. N03-002)
SEE NOTE A
OUTSIDE FACE VIEW
INSIDE FACE VIEW
BOTTOM VIEW
(Straight section)
R25.8
66.00"
62.00"
67.00"
NOTE A: 1. ALL ELECTRICAL UMBILICALS AND COOLING MANIFOLDS MUST BE CONTAINED WITHIN THE REGION DEFINED HERE.
2. WATER CONNECTIONS WILL MOUNT RADIALLY OUTWARD.
3. COOLING MANIFOLDS WILL BE MOUNTED BELOW ELECTRICAL CONNECTIONS.
MRC Mission Research Corporation
ELECTRA PRE-AMP MAGNET ASSEMBLY
N03-001
C





SECTION X - X

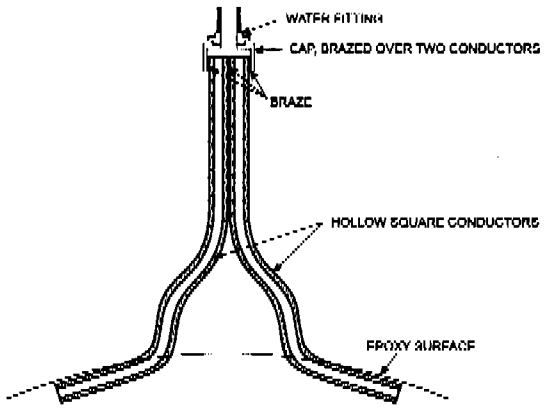


DETAIL Y

COIL WINDING 10 X 10
(5 DOUBLE PANCAKES,
"2-IN-HAND" WINDING)

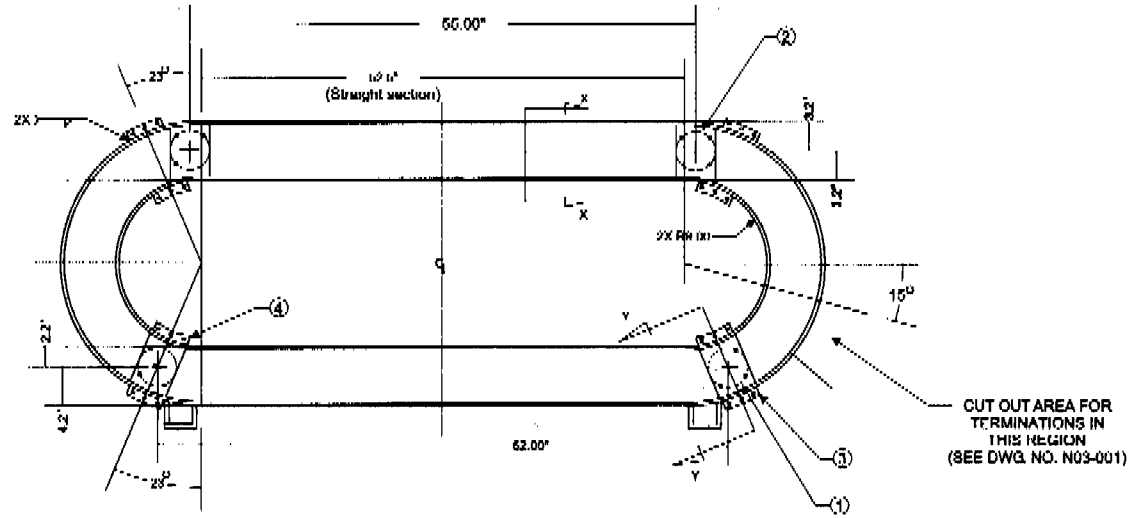
WIRE: COPPER, SQUARE W/ ROUND CHANNEL
WIRE CROSS SECTION: 0.480 - 0.515
CHANNEL: ø0.210 - ø0.250

REFER TO SPECIFICATIONS FOR ADDITIONAL WINDING INSTRUCTIONS

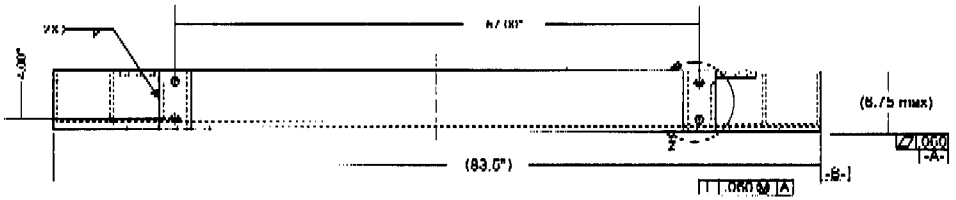


WIRE TERMINATION DETAIL

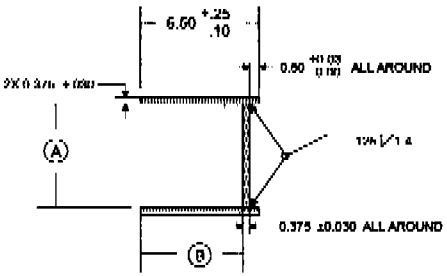
QTY	PART NO	MATERIAL SPECIFICATION PART LIST			ITEM NO
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE DECIMALS ANGLES X ± .06 ±1° .XX ± .01 .XXX ± .005		CONTRACT NO	MRC Massachusetts Research Corporation		
MATERIAL		DRAWN BY M JABARI	DATE 4/3/03	ELECTRA PRE-AMP MAGNET COIL ASSY	
FINISH		CHECKED J PARSONS	4/3/03		
DO NOT SCALE DRAWING		APPROVED		SIZE C	DWG NO N03-002 REV
				SCALE	SHEET



INSIDE FACE VIEW

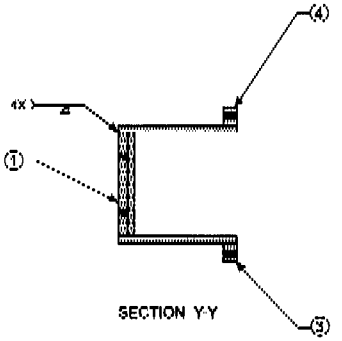


BOTTOM VIEW



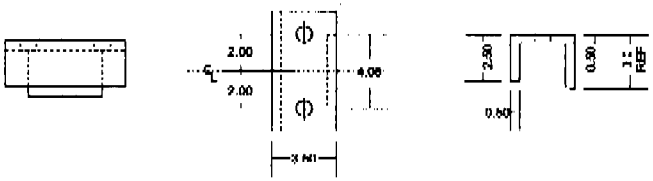
SECTION X - X

(A) (B)
NOTE: CAN DIMENSIONS "A" AND "B" TO FIT WINDING WITH ALLOWANCE FOR RUBBER STRIP BETWEEN WINDING AND CAN, ALL SIDES



SECTION Y-Y

NOTE. TWO CANS ARE REQUIRED.
THEY ARE MIRROR IMAGES OF ONE ANOTHER.



DETAIL Z
COIL MOUNTING BRACKET

QTY	PART NO.	MATERIAL/SPECIFICATION	REV NO.
4		INNER COIL CLAMP CAN WELDMENT (SEE DWG NO. N03-005)	4
4		OUTER COIL CLAMP CAN WELDMENT (SEE DWG NO. N03-006)	X
2		SPACER SUPPORT PLATES, UPPER (SEE DWG NO. N03-004)	2
2		SPACER SUPPORT PLATES, LOWER (SEE DWG NO. N03-004)	1

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
DECIMALS X ± .05, XX ± .01, XXX ± .005; ANGLES ±1°
MATERIAL: ALUMINUM 6061-T6
FINISH:
DO NOT SCALE DRAWING

CONTRACT NO.

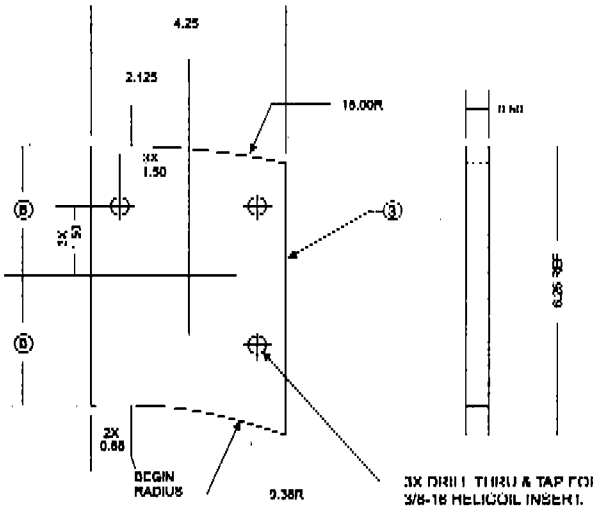
DRAWN BY	M JARAH	4/3/03
CHECKED	J FASOUR	4/3/03
APPROVED		

MRC Mission Research Corporation

ELECTRA PRE-AMP MAGNET CAN WELDMENT ASSY

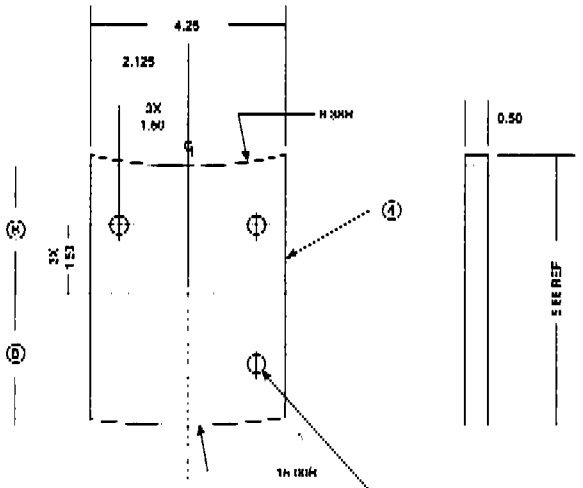
SIZE C | DWG. NO. N03-003 | REV

SCALE | SHEET



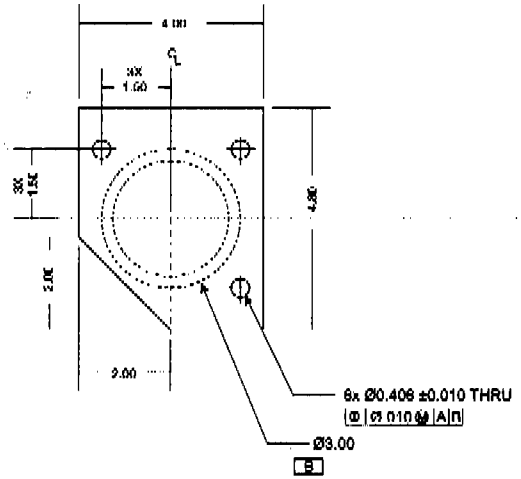
3X DRILL THRU & TAP FOR
3/8-16 HELICOIL INSERT.
NOTE: PARTS ARE ASSEMBLED AS MIRROR IMAGES.
SEE ASSEMBLY DWG. NO. N02-001
FOR HELICOIL INSERTION DIRECTION.

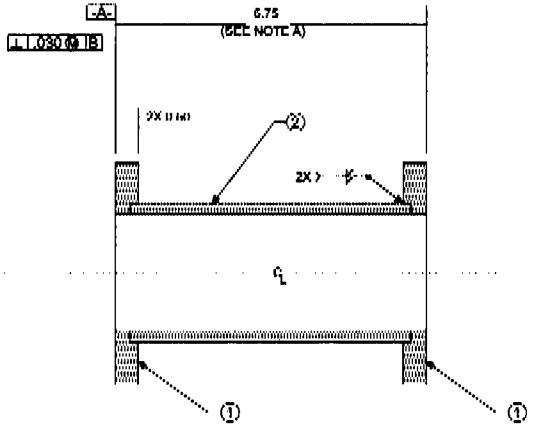
(10) NOTE, DIMENSION B: MOUNTING PLATES MUST FIT CAN.
"B" WILL DEPEND ON CAN WIDTH, WHICH WILL
DEPEND ON ACTUAL WIRE CROSS SECTION USED.



3X DRILL THRU & TAP FOR
3/8-16 HELICOIL INSERT.
NOTE: PARTS ARE ASSEMBLED AS MIRROR IMAGES.
SEE ASSEMBLY DWG. NO. N02-001
FOR HELICOIL INSERTION DIRECTION

NOTE: UPPER AND LOWER SUPPORT PLATES ARE WELDED TO
THE INSIDE FACES OF MAGNET CANS. SEE DWG NO. N02-001
AND N02-005 FOR LOCATION





NOTE A. OVERALL LENGTH OF ASSEMBLED
MAGNET PAIR (EXCLUDING COIL CLAMPS)
MUST NOT EXCEED 20.00. SPACER LENGTH
CAN BE REDUCED TO 6.50 IF NECESSARY
TO MAINTAIN OVERALL LENGTH CONSTRAINT.

ITEM	PART NO	MATERIAL SPECIFICATION	QTY
4		LOWER SUPPORT PLATE, ALUM 6061T6	4
3		UPPER SUPPORT PLATE, ALUM 6061T6	4
2		TUBE, 3.00 X .25 NOM. WALL THK. ALUM 6061T6511	4
1		PLATE, ALUM 6061T6	A

PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ARE
DECIMALS .X ±.06 .XX ±.04 .XXX ±.000
ANGLES ±1°

CONTRACT NO

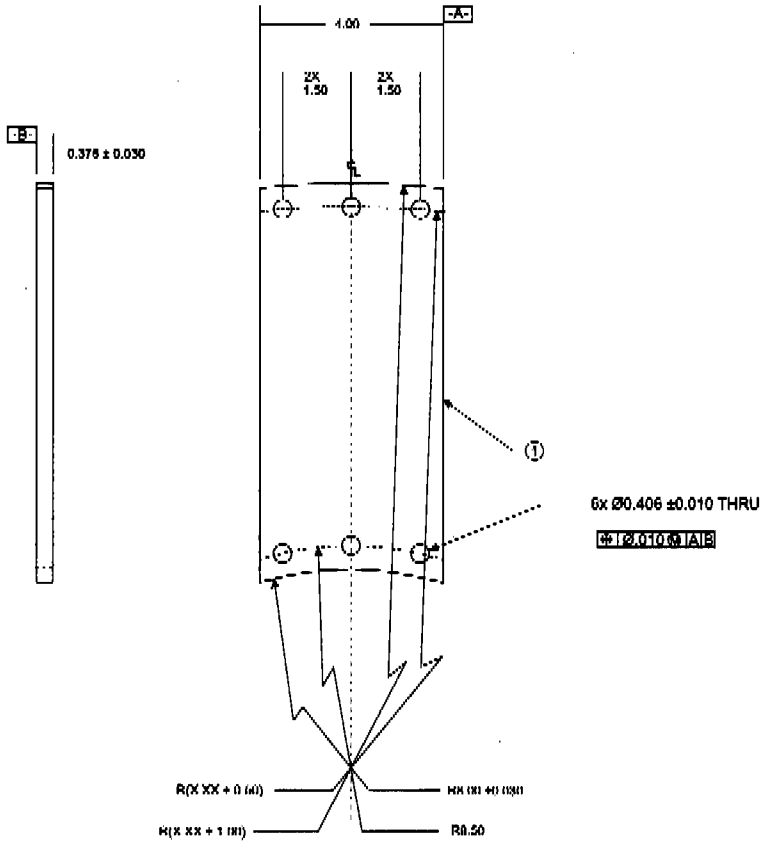
MRC Mission Research Corporation

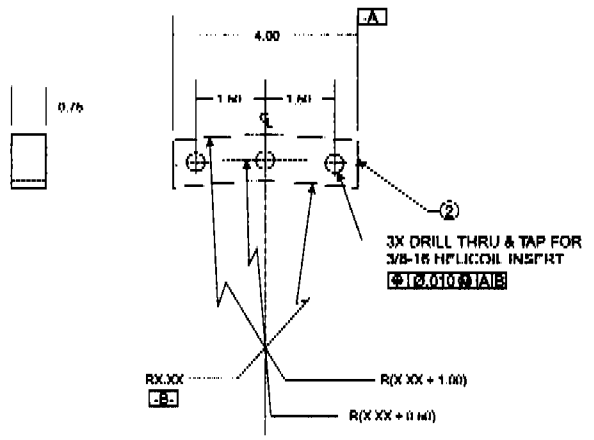
	NAME	DATE
DRAWN	M JABARI	4/3/03
CHECKED	J PARKER	4/3/03
APPROVED		

MATERIAL
FINISH
DO NOT SCALE DRAWING

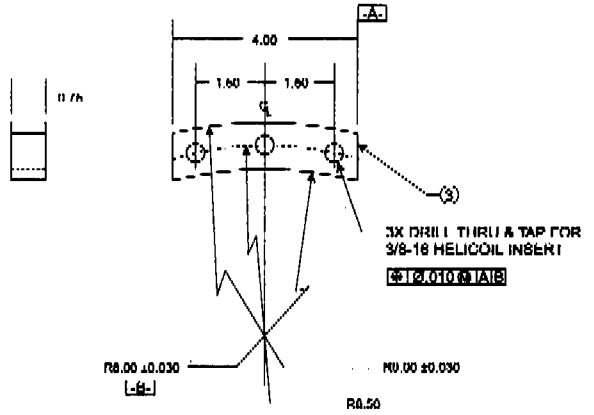
ELECTRA PRE-AMP
MAGNET SPACER

SIZE C | DWG NO. N03-004 | REV
SCALE | SHEET





NOTE: RADIUS X.XX TO MATCH OUTER RADIUS OF COIL CAN.



ITEM	QTY	PART NO	MATERIAL /SPECIFICATION
3	X		INNER CAN WELDMENT
2	8		OUTER CAN WELDMENT
1	8		CLAMP PLATE

PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE
DECIMALS ANG FR
.X ±.05 ±1°
.XX ±.01
.XXX ±.005
MATERIAL: ALUMINUM 6061T6
FINISH
DO NOT SCALE DRAWING

CONTRACT NO

		DATE
DRAWN BY	M JABARI	3/24/03
CHECKED	J PASOUR	3/24/03
APPROVED		

MRC Mission Research Corporation

ELECTRA PRE-AMP
MAGNET COIL CLAMP

SIZE C | DWG NO. N03-005 | REV
SCALE | SHEET